

CLAIMS

What is claimed is:

1. An optical transmission system comprising:
 - 5 a plurality of optical processing nodes configured to optically communicate via optical signals in a signal wavelength range; and,
 - a plurality of signal varying devices positioned to vary an optical signal passing between the processing nodes,
 - 10 wherein the plurality of signal varying devices includes:
 - a first signal varying device at a first location including optical fiber provided with optical energy in a first set of pump wavelengths from a first pump source to produce Raman gain having a first signal variation
 - 15 profile in the optical signals over the signal wavelength range, and
 - a second signal varying device at a second location remote from the first location and configured to provide a second signal variation profile over the signal
 - 20 wavelength range, wherein the first and second signal variation profiles provide for a cumulative signal variation profile over the signal wavelength range that differs from either of the first and second signal variation profiles.
- 25 2. The system of claim 1 wherein the first pump source is configured to vary at least one of the pump energy carried by at least one of the pump wavelengths and at least one of the pump wavelengths to control at least the first signal variation profile.
- 30 3. The system of claim 1 wherein the first pump source includes pump wavelengths selected to provide a substantially uniform signal variation profile over the signal wavelength range.

4. The system of claim 1 wherein the second signal varying device includes at least one doped optical fiber configured to optically amplify the optical signals; and

the first pump source is further configured to supply
5 pump energy to optically amplify optical signals in the doped fiber.

5. The system in claim 4 wherein the first pump source includes pump wavelengths selected to provide an adjustable overall gain profile over the signal wavelength range.

10 6. The system in claim 4 wherein the optical fiber includes at least a portion of transmission fiber in the optical transmission system.

7. The system in claim 4 wherein the first pump source includes pump wavelengths selected to provide a substantially
15 uniform overall gain profile over the signal wavelength range.

8. The system in claim 4 wherein the first pump source includes pump wavelengths selected to provide different Raman and doped fiber gain profiles over the at least one signal
20 wavelength range.

9. The system of claim 4 wherein the doped fiber includes at least one erbium doped fiber.

10. The system of claim 9 wherein the first pump source is configured to control the pump wavelength to provide a
25 Raman gain profile that substantially compensates for gain non-uniformities introduced by the at least one erbium doped fiber.

11. The system of claim 4 further comprising at least one wavelength selective reflector positioned to reflect a
30 portion of the pump energy from at least one pump wavelength back toward the first pump source.

12. The system of claim 11 wherein the at least one wavelength selective reflectors includes at least one fiber Bragg grating positioned to reflect the portion of the at least one pump wavelength before reaching the doped fiber.

5 13. The system of claim 10 wherein the first pump source is configured to supply pump energy in at least one wavelength that is not absorbed by the doped fiber and to provide Raman gain in the optical fiber.

10 14. The system of claim 1 wherein the first pump source is remotely located from the optical fiber and delivers the pump energy to the optical fiber via a separate pump path.

15 15. The system of claim 1 wherein the optical fiber includes first and second Raman fiber, the first Raman fiber having different Raman gain characteristics than the second Raman fiber; and

the first pump source is configured to provide pump energy in pump wavelengths to produce Raman gain in the first and second Raman fibers.

20 16. The system of claim 1 wherein the first Raman fiber includes optical fibers having a smaller core than the second Raman fiber.

17. The system of claim 16 wherein the first pump source is configured to provide a common source of pump energy to the first and second Raman fibers.

25 18. The system of claim 17 wherein the second Raman fiber provides for low loss in the 1420 to 1510 nm range and pump energy is transmitted through the second Raman fiber to the first Raman fiber.

30 19. The system of claim 16 wherein the first pump source is configured to provide different Raman pump wavelengths to the first Raman fiber and the second Raman fiber.

20. The system of claim 1 wherein the second signal
varying device includes a second pump source configured to
provide pump energy in at least a second set of Raman
wavelengths to provide Raman gain in the first set of Raman
5 wavelengths in the optical fiber.

21. The system of claim 20 wherein the second set of
Raman wavelengths is counter-propagated in the optical fiber
relative to the first set of Raman wavelengths.

22. The system of claim 20 wherein the first pump
10 source includes a third set of Raman wavelengths to provide
Raman gain to the second set of Raman wavelengths.

23. The system of claim 1 wherein a portion of the
optical fiber provides for distributed Raman gain and another
portion of the optical fiber provides for concentrated Raman
15 gain.

24. The system of claim 23 further comprising a gain
flattening filter positioned to impart a signal variation
profile over at least a portion of at least one signal
wavelength range.

25. The system of claim 1 wherein the pump wavelengths
are selected to provide a cumulative signal variation profile
over the signal wavelength range having a variation of
20 $< \pm 1$ dB.

26. The system of claim 1 wherein the device is
25 operable in at least one signal varying mode, the mode
selected from the group consisting of amplification,
attenuation, and lossless transmission.

27. The system of claim 1 wherein the optical fiber is suitable for transmitting a plurality of signal wavelength ranges; and

the first pump source is configured to provide a
5 plurality of pump wavelength interleaved with the plurality of signal wavelength ranges and having sufficient pump energy to produce Raman gain in a plurality of signal varying profiles in the plurality of signal wavelength ranges.

28. The system of claim 1 wherein the optical fiber is
10 configured to produce Raman gain in a signal wavelength range and provide concentrated amplification, attenuation, and lossless transmission in the optical fiber; and

the first pump source is configured to provide pump
energy to the optical fiber in a plurality of pump
15 wavelengths having sufficient pump energy to produce Raman gain and a signal variation profile in the signal wavelength range and the pump source is further configured to control the pump energy in at least one of the pump wavelengths to vary the signal variation profile and provide amplification,
20 attenuation, and lossless transmission in the optical fiber over the signal wavelength range.